Learning Machines
An introduction

Luc De Raedt
Dept. Computer Science
luc.deraedt@cs.kuleuven.be

KATHOLIEKE UNIVERSITEIT LEUVEN

Overview

- What is machine learning ?
- Why is it useful ?
- What is behind it ?

What is Machine Learning ?

Machine Learning

A *machine* learns when

- it improves it *performance*
- on a specific *task*
- with *experience*

Central to Artificial Intelligence & Cognitive Systems

AlphaGo

AlphaGo

Machine = AlphaGo Computer Program

Task = playing GO

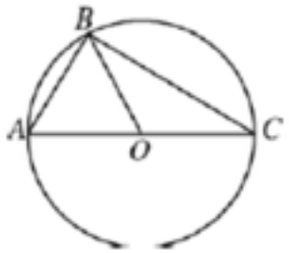
Performance = % of won games

Experience = huge data base of games

Euclid (Allen AI Institute)

GeoS Demo – An End to End Geometry Problem Solver

In the figure above, triangle ABC is inscribed in the circle with center O and diameter AC. If AB=AO, what is the degree measure of angle ABO?



(A) 15°
(B) 30°
(C) 45°
(D) 60°
(E) 90°

Solve Problem

Euclid

Machine = Euclid Computer Program

Task = answering SAT questions

Performance = % of correct answers

Experience = reading the web, textbooks, past examples

Watson / Jeopardy

machine reading

Robot Scientist

King et al. Science 2009

Robot Scientist

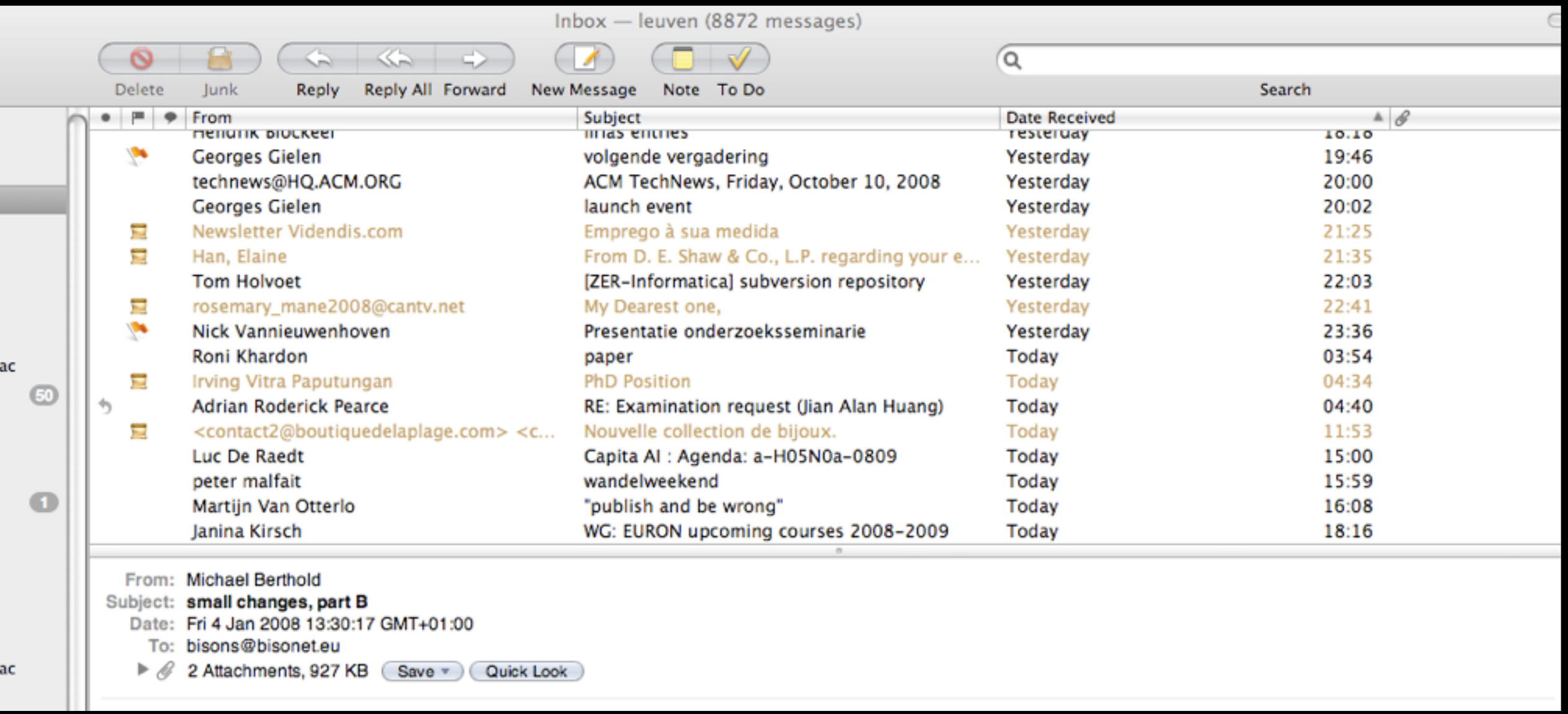
Machine = Robot

Task = find highest activity molecule

Performance = nof. experiments / reliability of model

Experience = past experiments and data

Spam Filter


Inbox — leuven (8872 messages)
Delete
Junk
Reply
Reply All
Forward
New Message
Note
To Do
Search
From
Subject
Date Received
Georges Gielen volgende vergadering Yesterday 19:46
technews@HQ.ACM.ORG ACM TechNews, Friday, October 10, 2008 Yesterday 20:00
Georges Gielen launch event Yesterday 20:02
Newsletter Videndis.com Emprego à sua medida Yesterday 21:25
Han, Elaine From D. E. Shaw & Co., L.P. regarding your e... Yesterday 21:35
Tom Holvoet [ZER-Informatica] subversion repository Yesterday 22:03
rosemary_mane2008@cantv.net My Dearest one, Yesterday 22:41
Nick Vannieuwenhoven Presentatie onderzoeksseminarie Yesterday 23:36
Roni Khardon paper Today 03:54
Irving Vitra Paputungan PhD Position Today 04:34
Adrian Roderick Pearce RE: Examination request (Jian Alan Huang) Today 04:40
<contact2@boutiquedelaplage.com> <c... Nouvelle collection de bijoux. Today 11:53
Luc De Raedt Capita AI : Agenda: a-H05N0a-0809 Today 15:00
peter malfait wandelweekend Today 15:59
Martijn Van Otterlo "publish and be wrong" Today 16:08
Janina Kirsch WG: EURON upcoming courses 2008-2009 Today 18:16
From: Michael Berthold
Subject: small changes, part B
Date: Fri 4 Jan 2008 13:30:17 GMT+01:00
To: bisons@bisonet.eu
2 Attachments, 927 KB
Save
Quick Look

Spam Filter

Machine = e-mail program, spamfilter

Task = classify e-mails

Performance = accuracy

Experience = your past input

Why is it useful ?

Why Machine Learning ?

Artificial Intelligence

Machine Learning is very practical

- some programs are too complex to program by hand (spam, go …)
- adaptation and personalisation
- analysing data (data mining), discovering new knowledge

"we are drowning in data but starving for knowledge"

Numerous applications

- The enabling technology in
  - natural language processing
  - computer vision
  - robotics
  - data mining / data analysis
    - medical, financial, biology, chemistry, engineering, analytics, …

How does Machine Learning work ?

How does it work?

Machine learning is all about learning functions.

- different types of functions
- different types of data
- different criteria (loss functions)

and there are

- different schools of thought in ML

More formally

Given

- a space of possible instances X
- an unknown target function f: X → Y
- a hypothesis space L containing functions X → Y
- a set of examples E = { (x, f(x)) | x ∈ X }
- a loss function *loss*(h,E) → $\mathbb{R}$

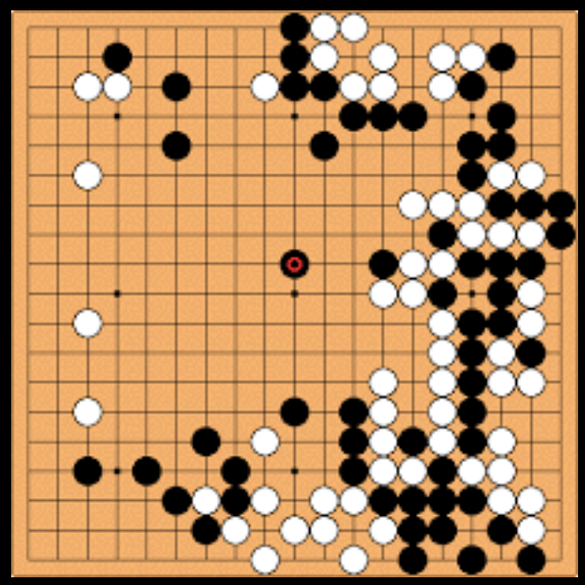
Find h ∈ L that minimizes *loss*(h,E)

supervised

Machine Learning = Variations on this problem

Learning functions

- Spam
  - f(e-mail) = spam of geen spam
- Go
  - f(board) = 9-13 predict move (policy)
  - f(board, 9-13) = good /bad
  - P(board,9-13) = probability of play
  - Q(board,9-13) = expected “reward”



What kind of data ?

learning from examples *(supervised / unsupervised)*

- good/bad moves ? just moves ?

learning by imitation *(Behavioral cloning)*

- imitate de world champion

learning from rewards *(Reinforcement learning)*

- just play, reward = board config. / wins / losses
- the whole AI problem in a nutshell

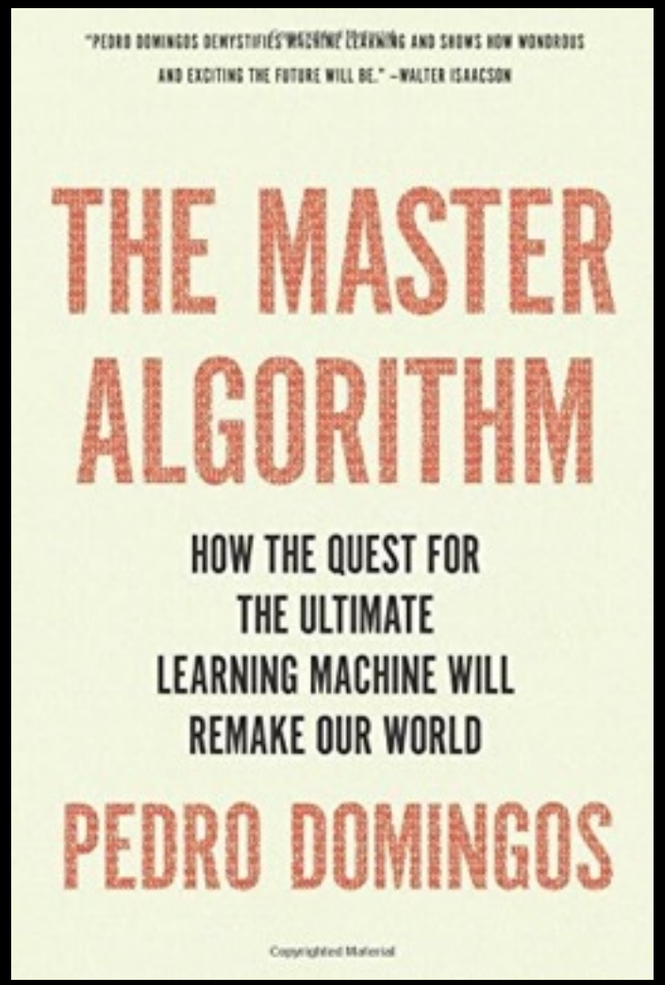
Where does the data come from ?

Learning simultaneously

- GO :
  - learn which moves champions can take (classification)
  - learn by reinforcement by playing
- Euclid
  - learn to map language -> model
  - learn to solve model

The five tribes of ML

Tribe	Origins	Master Algorithm
Symbolists	Logic, philosophy	Inverse deduction
Connectionists	Neuroscience	Backpropagation
Evolutionaries	Evolutionary biology	Genetic programming
Bayesians	Statistics	Probabilistic inference
Analogizers	Psychology	Kernel machines



According to Pedro Domingos

NELL: http://rtw.ml.cmu.edu/rtw/

Logic (machine reading)

Recently-Learned Facts twitter

Refresh

instance	iteration	date learned	confidence
kelly_andrews is a female	826	29-mar-2014	98.7
investment_next_year is an economic sector	829	10-apr-2014	95.3
shibenik is a geopolitical entity that is an organization	829	10-apr-2014	97.2
quality_web_design_work is a character trait	826	29-mar-2014	91.0
mercedes_benz_cls_by_carlsson is an automobile manufacturer	829	10-apr-2014	95.2
social_work is an academic program at the university rutgers_university	827	02-apr-2014	93.8
dante wrote the book the_divine_comedy	826	29-mar-2014	93.8
willie_aames was born in the city los_angeles	831	16-apr-2014	100.0
kitt_peak is a mountain in the state or province arizona	831	16-apr-2014	96.9
greenwich is a park in the city london	831	16-apr-2014	100.0

instances for many different relations

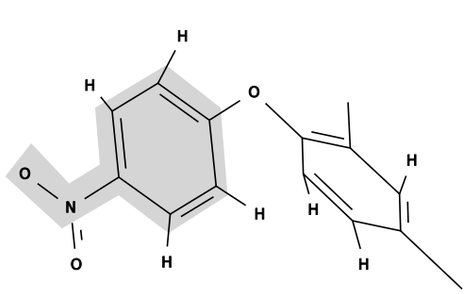
degree of certainty

Learn rules :

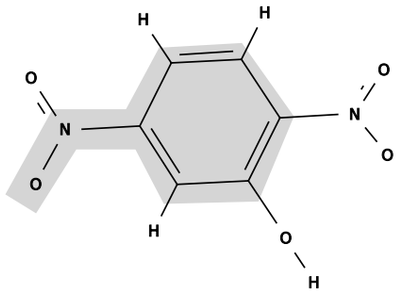
IF Person was Born in City AND City Lies-in Country
THEN Person was Born in Country

IF Person was Born in Country
THEN Person has Nationality Country

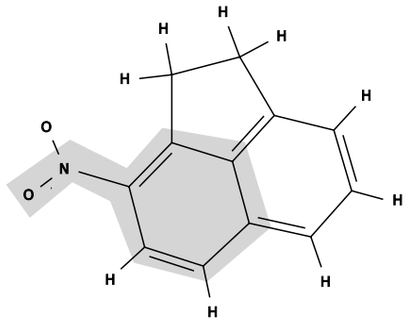
Structure Activity Relationship Prediction



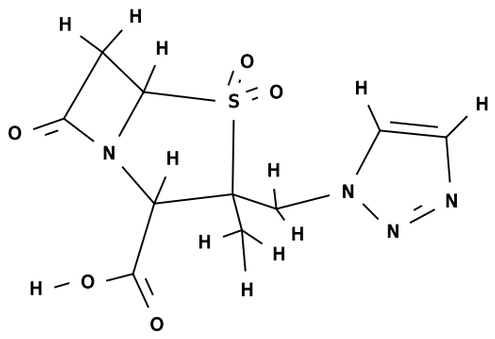
Mutagenic



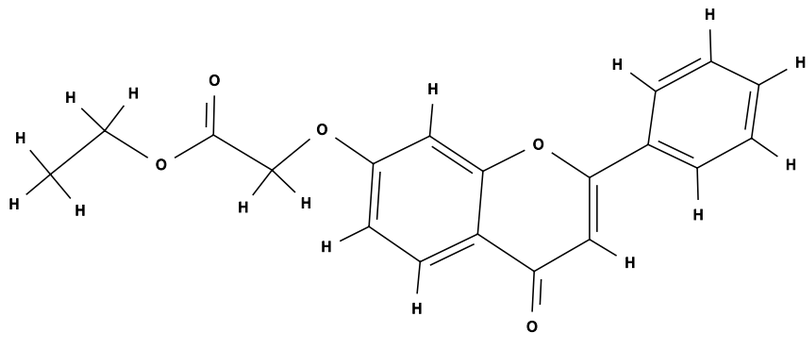
Mutagenic



Mutagenic



Clean



Clean

Molecules are graphs

Patterns are subgraphs

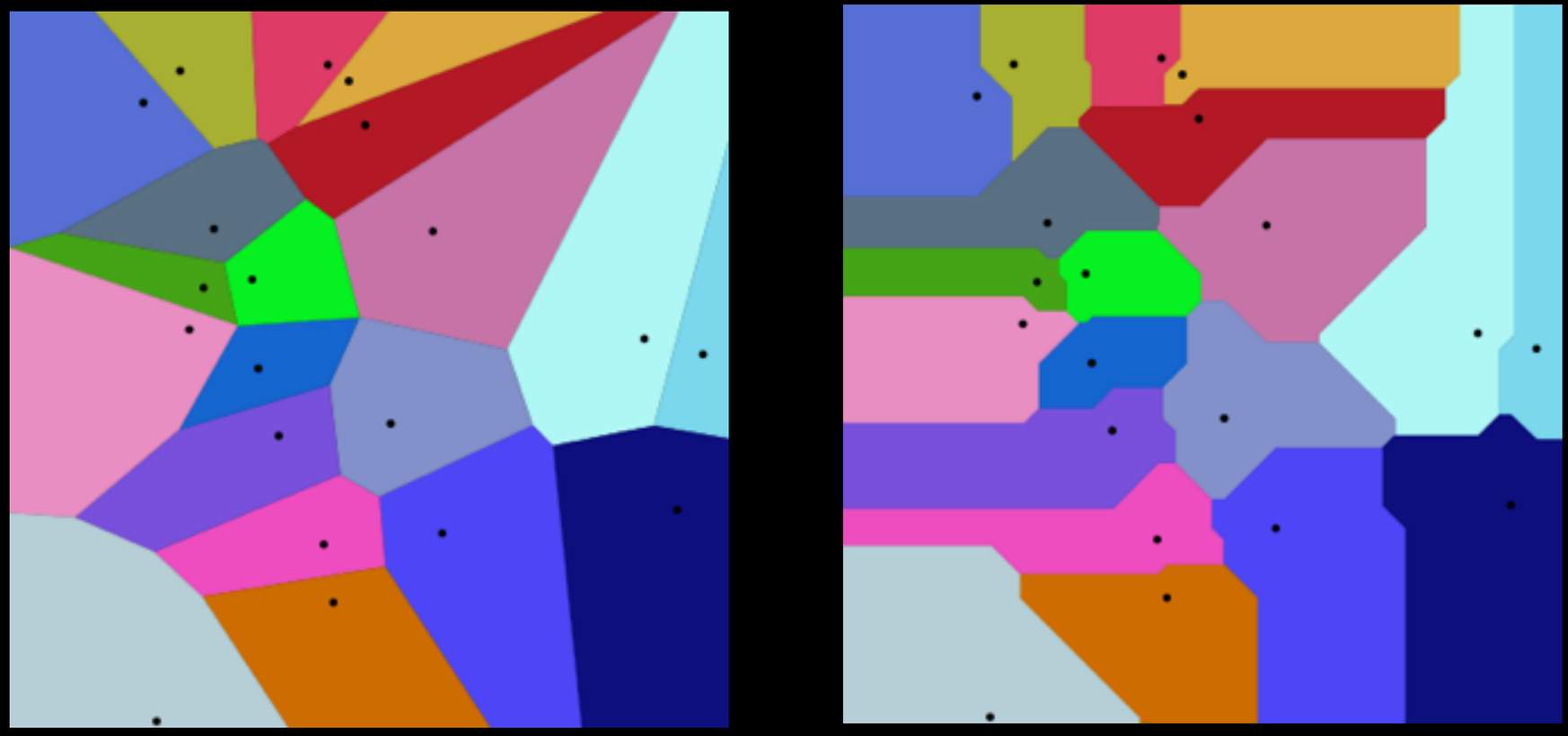
Search for “best”/ most relevant patterns

Figure: Siegfried Nijssen

Interpretable knowledge

Analogizers
Nearest Neighbor

- Similarity / Distance measures / Kernels
- k- Nearest Neighbor / Support Vector Machines



Voronoi Diagrms

Probabilistic / Bayesian

Posterior :
how likely is the function
given the data ?

Likelihood:
how likely is it
that the function
generates the data ?

Prior
how likely
is this function ?

$$P(Function|Data) = \frac{P(Data|Function) \times P(Function)}{P(Data)}$$

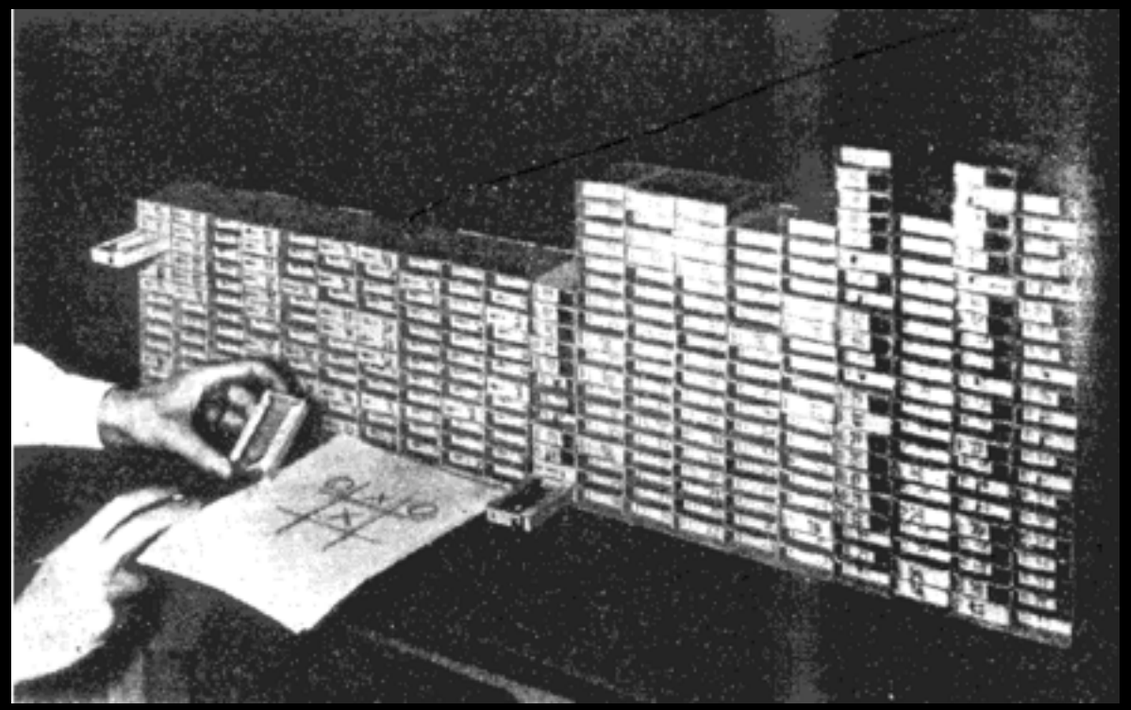
Law of Reverent Thomas Bayes.

Probabilistic graphical models.

An early reinforcement learning system

Donald Michie's Menace

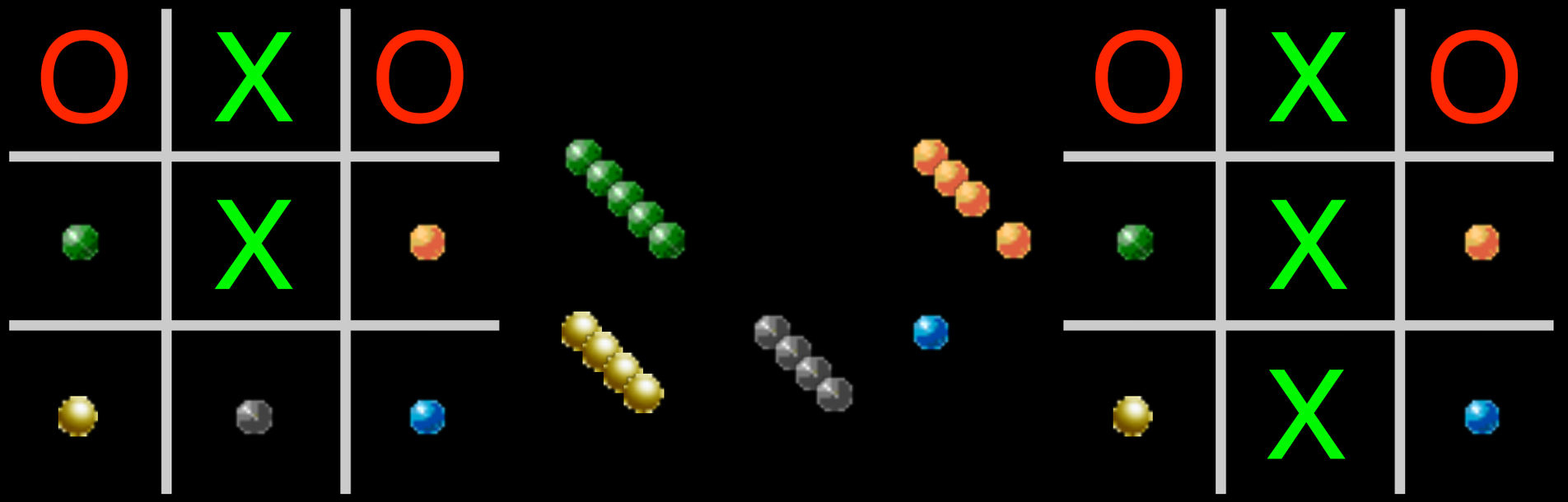
Donald Michie (2007)



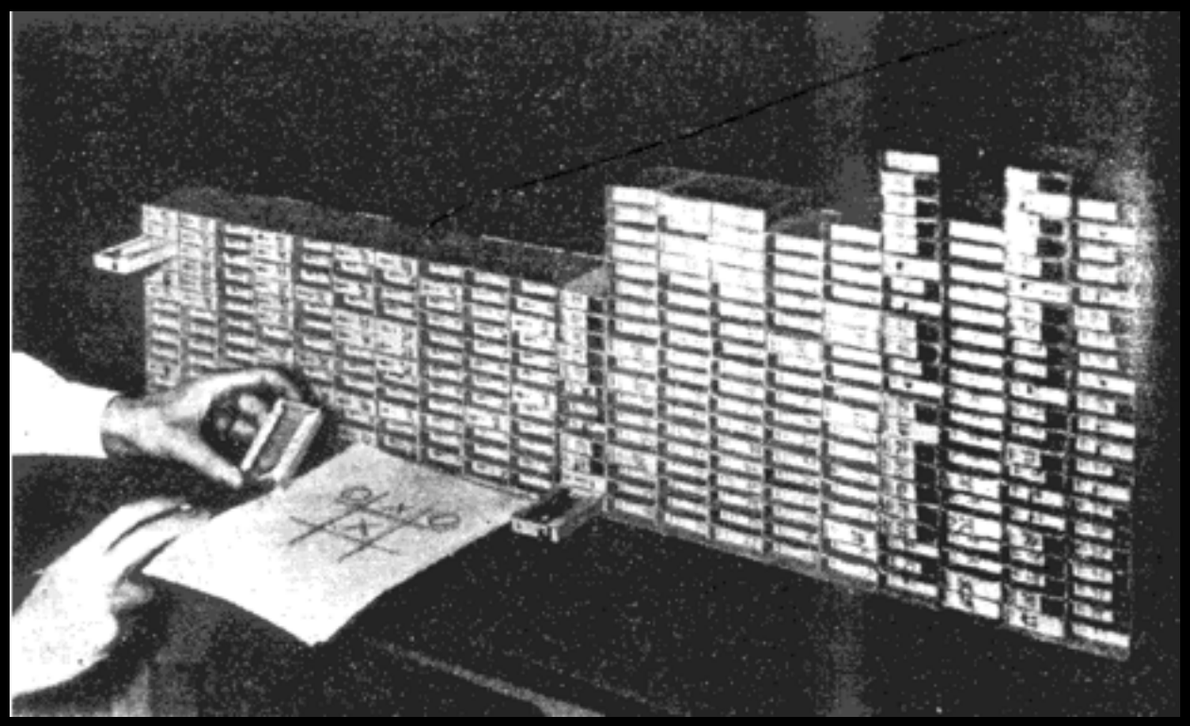
Menace (1961)

Machine Educable Noughts And Crosses Engine

X's move



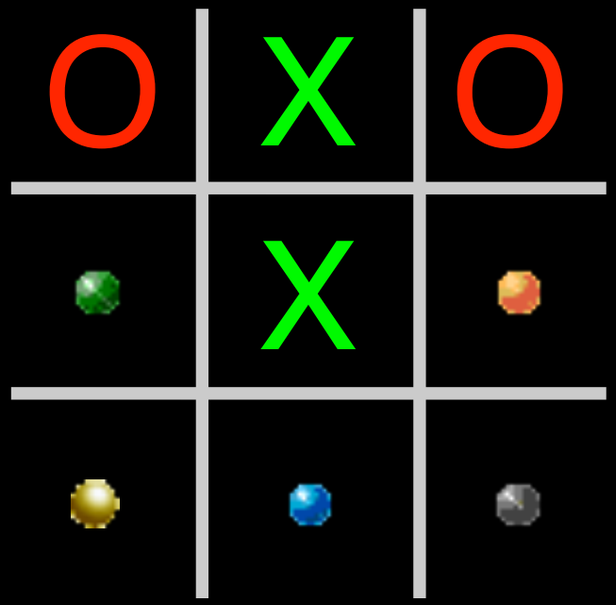
Choose box on the basis of current position



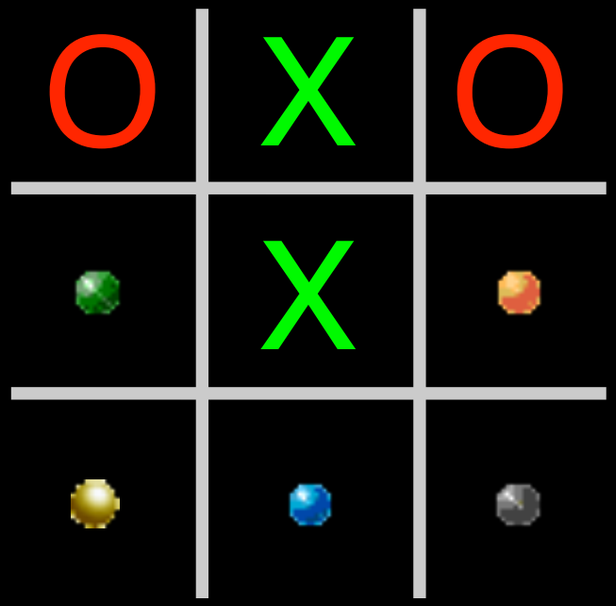
Select pearl from box at random

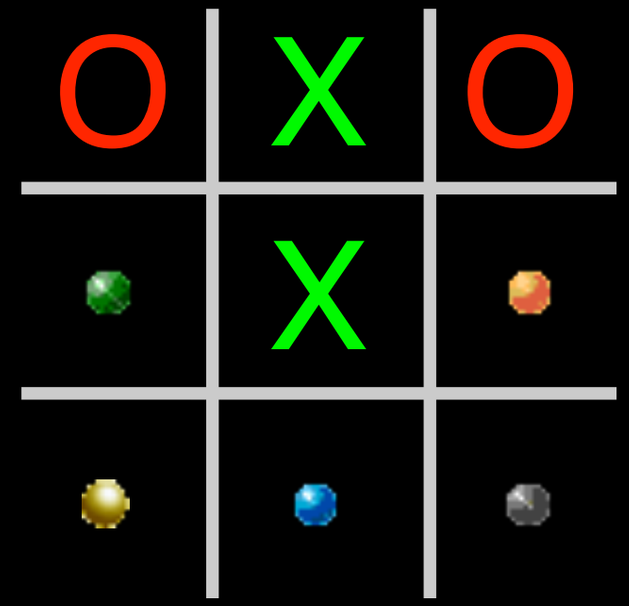
Execute move

X's
move

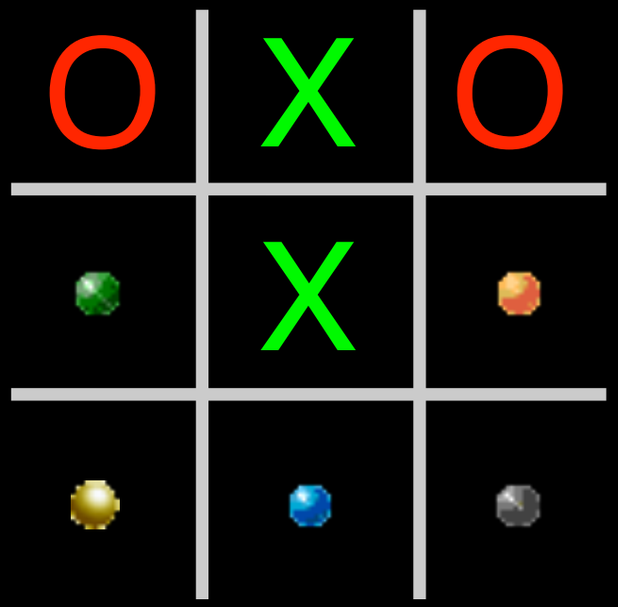


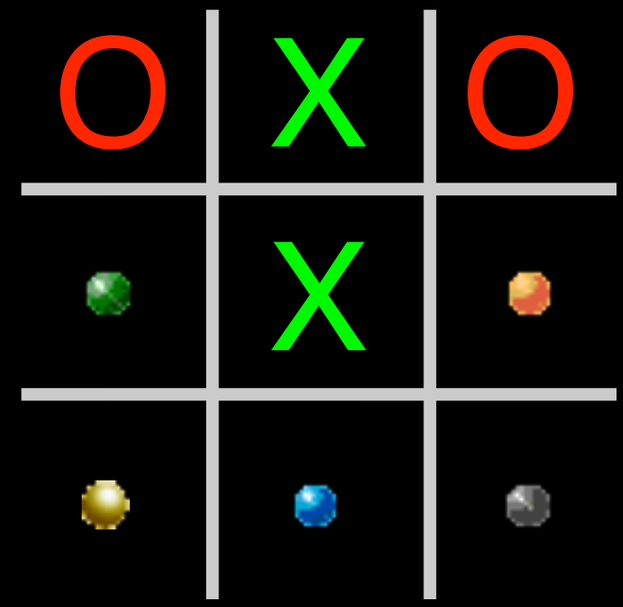
X's move

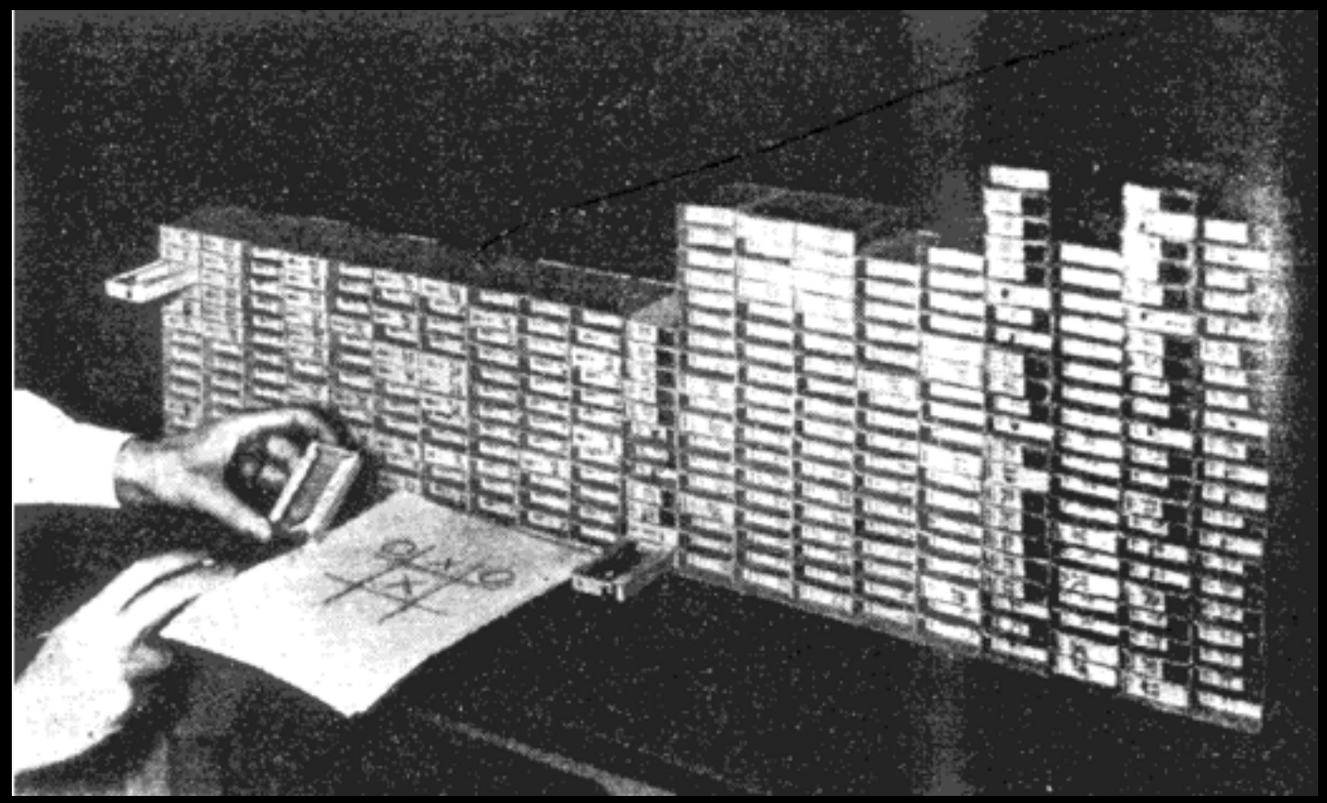




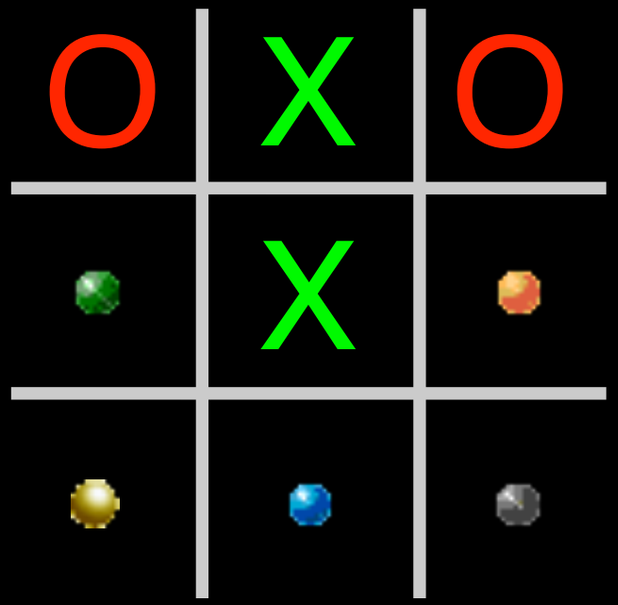
X's move

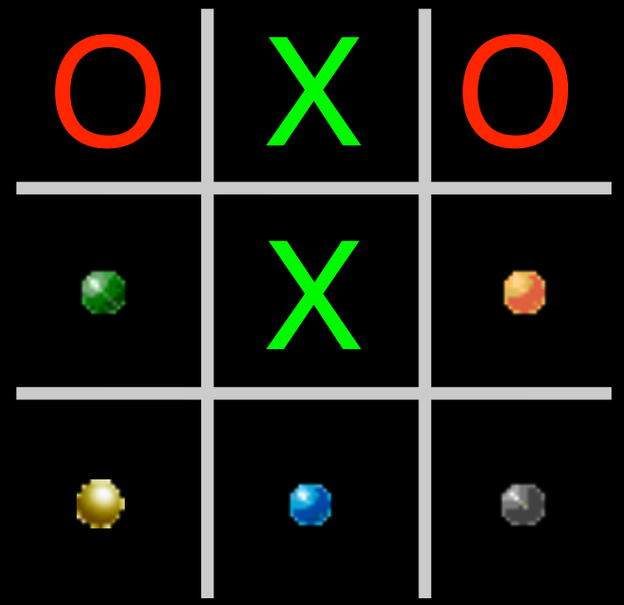


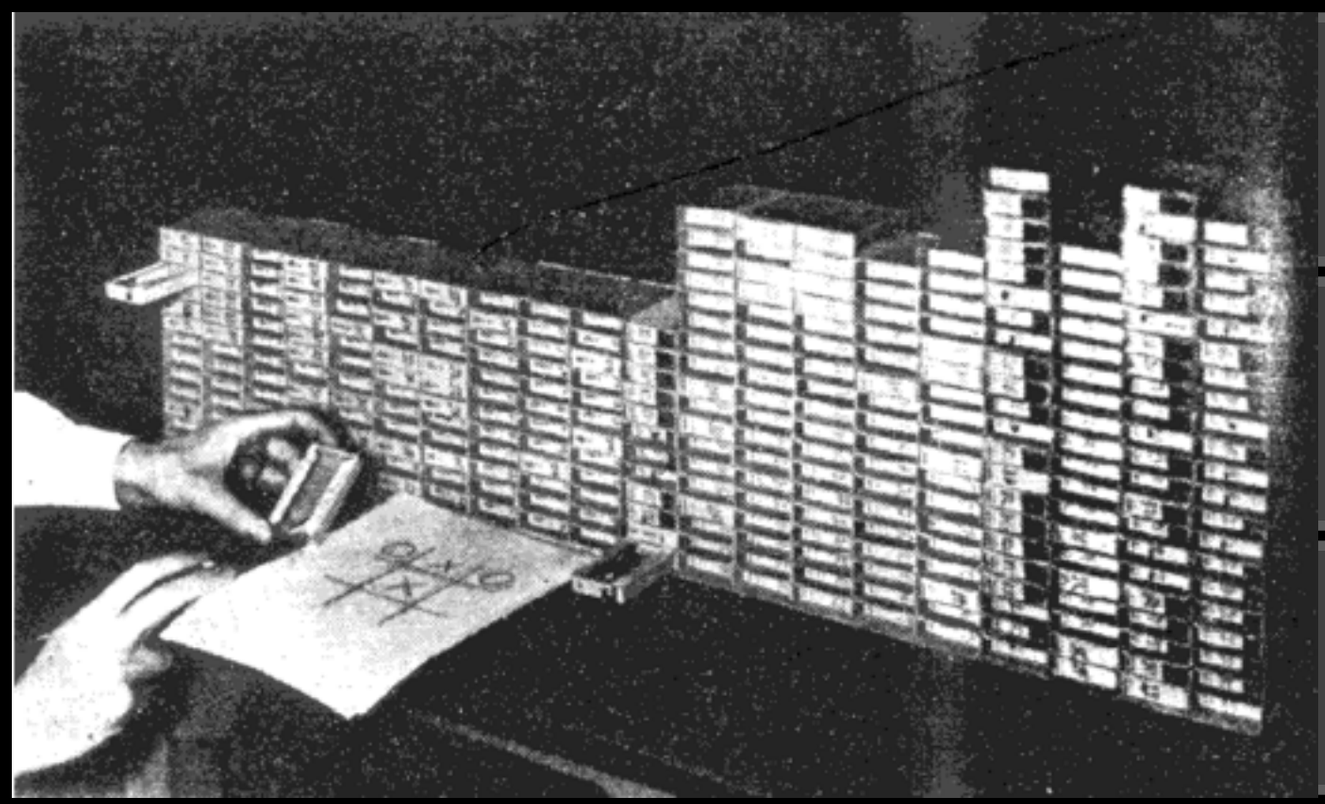




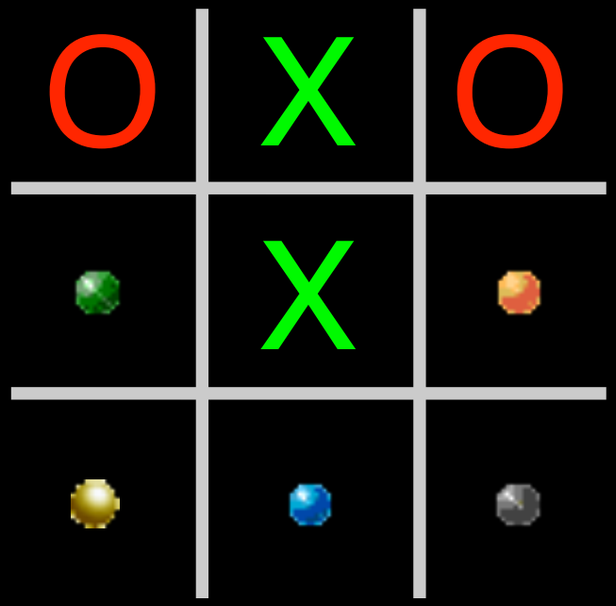
X's move

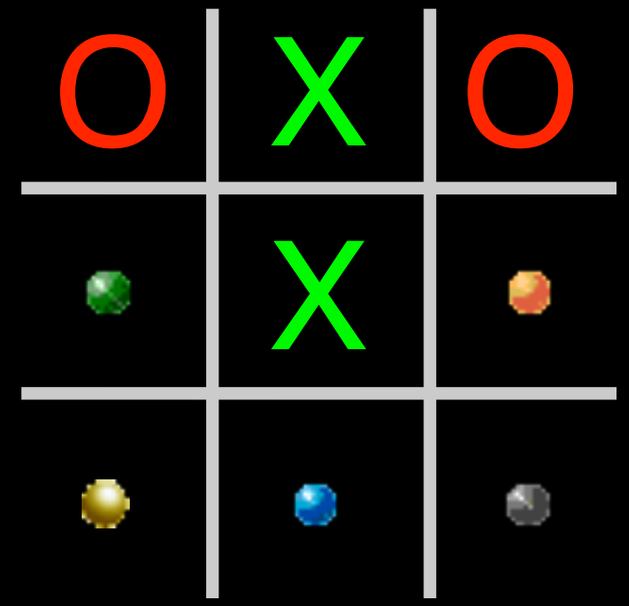




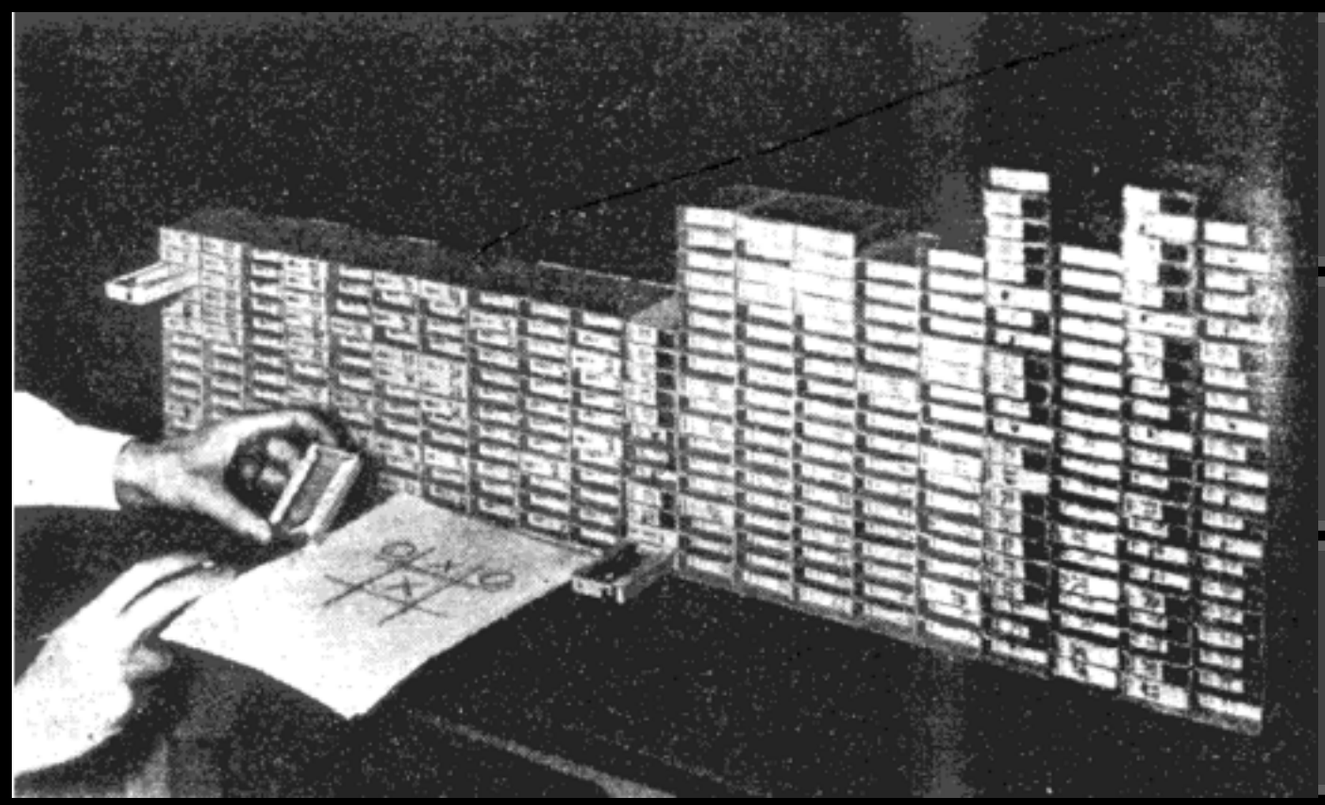


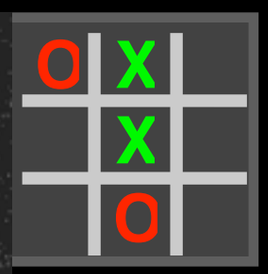
X's move

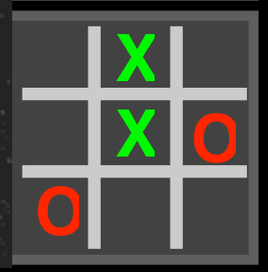




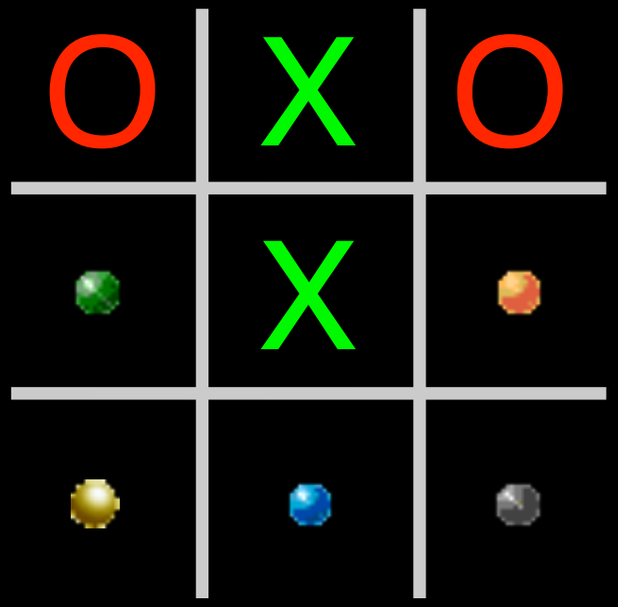
Choose box on the basis of current position

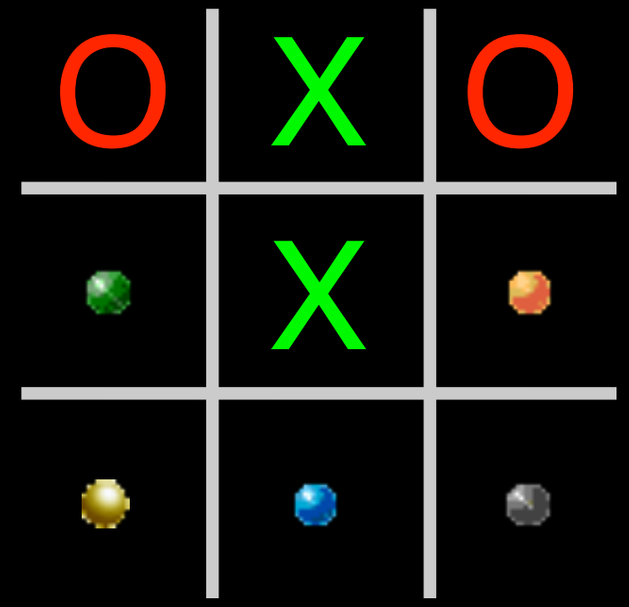




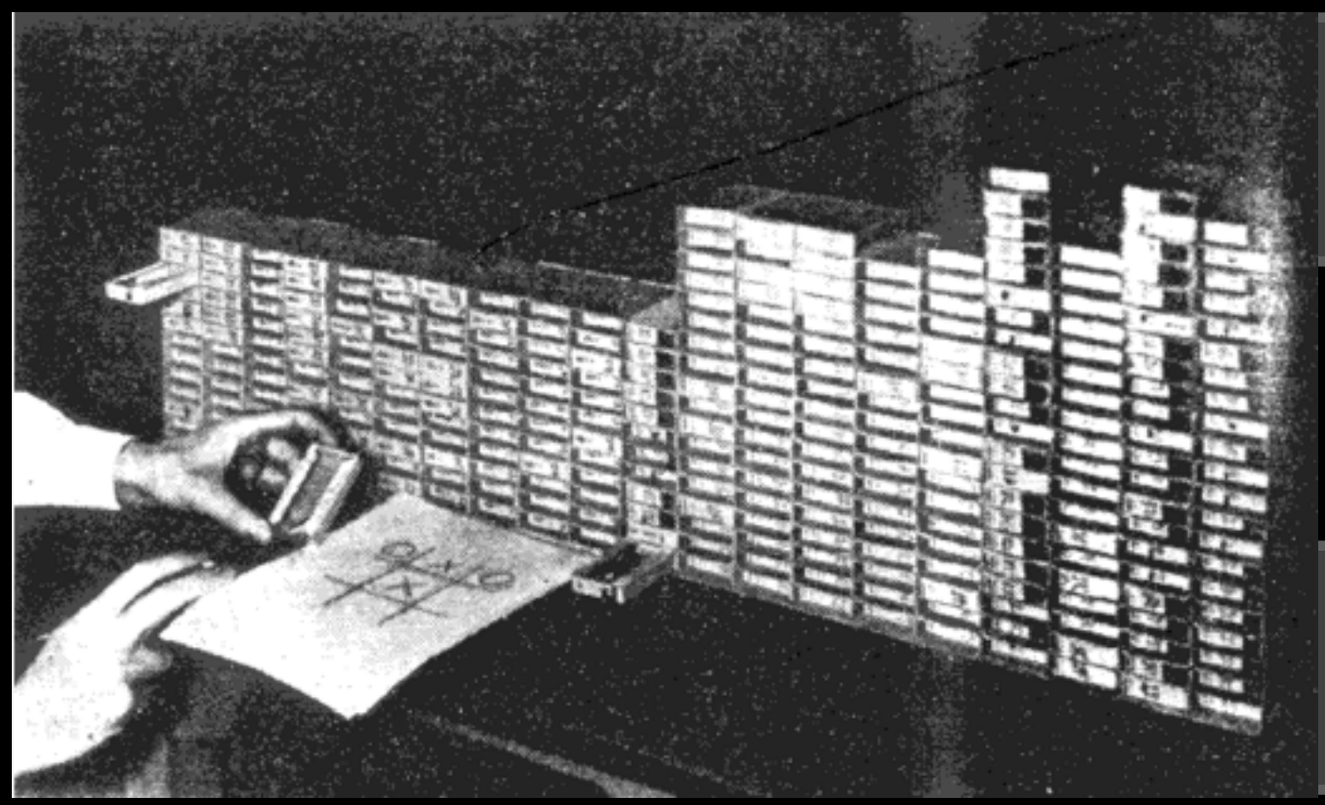


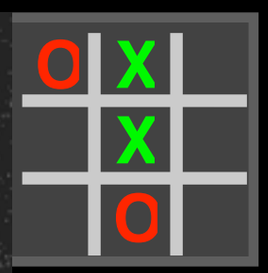
X's move

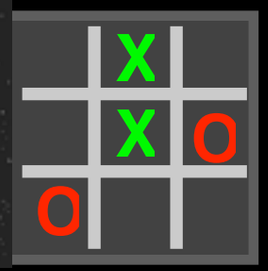


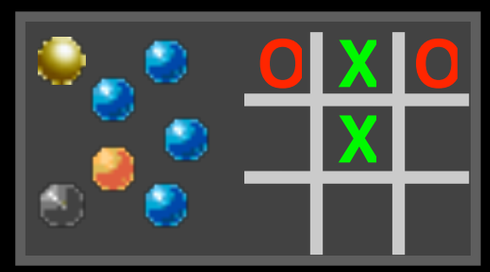


Choose box on the basis of current position

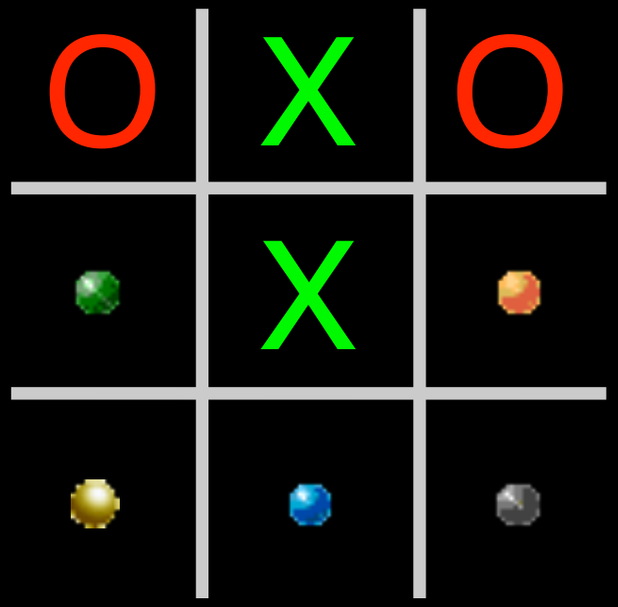


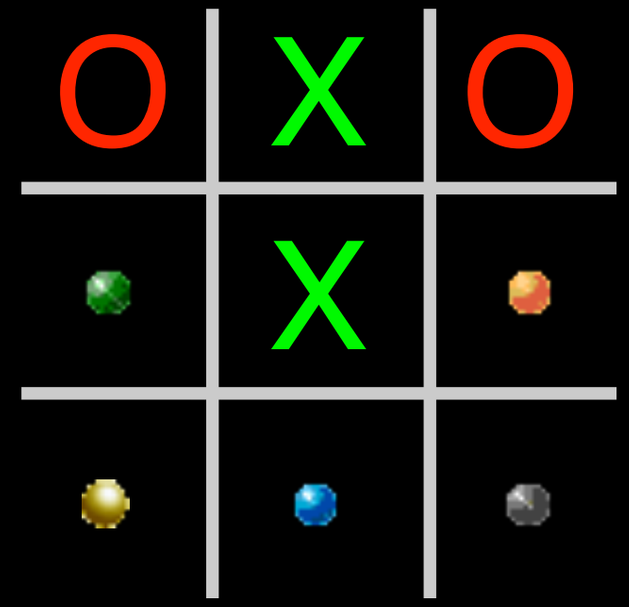




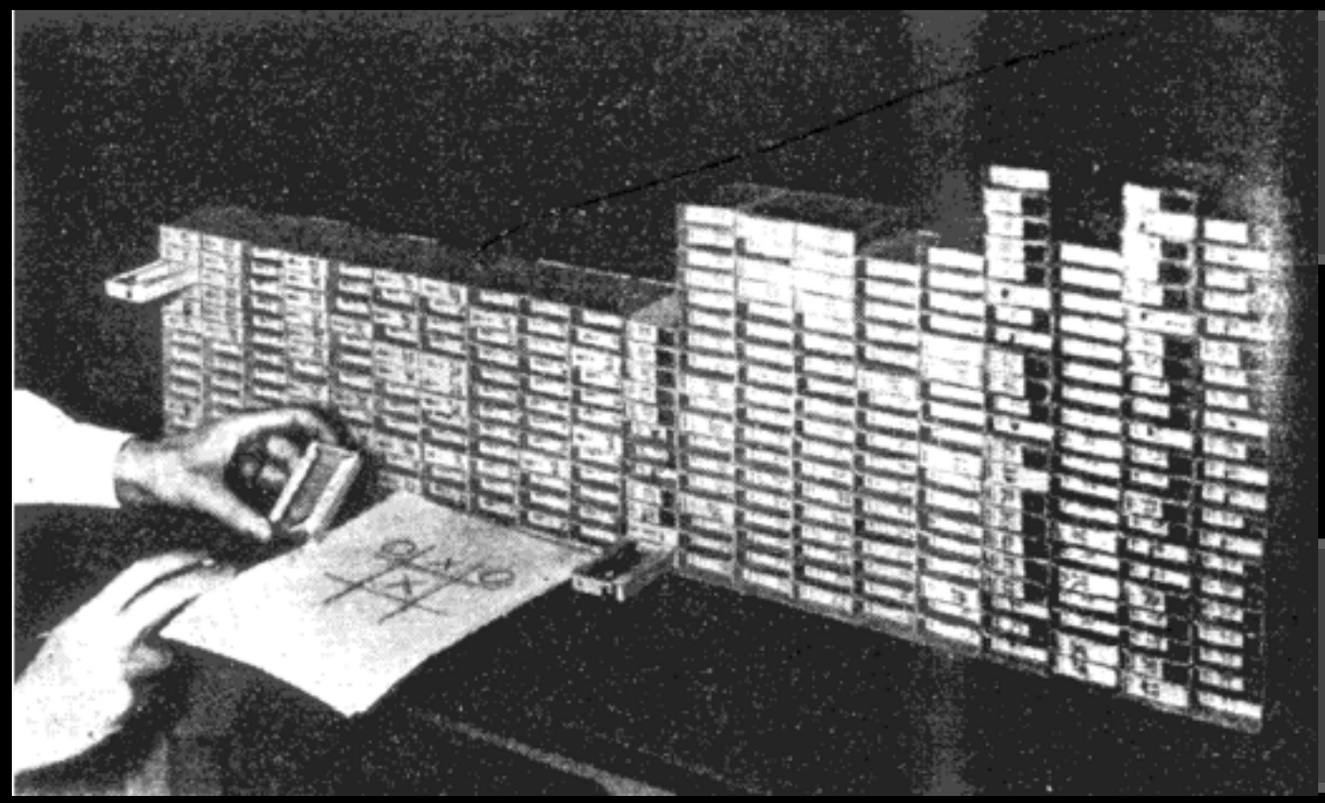


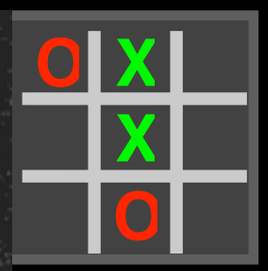
X's move

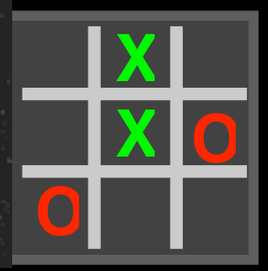


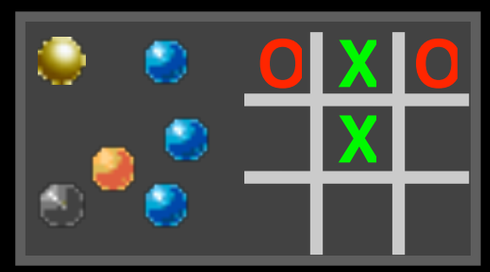


Choose box on the basis of current position

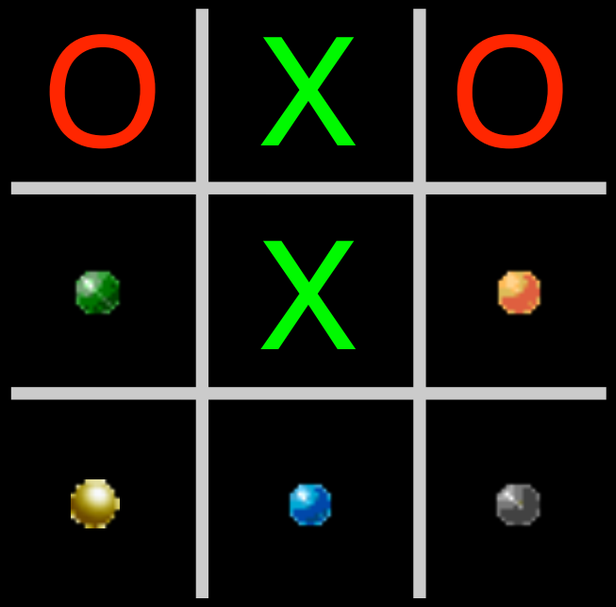






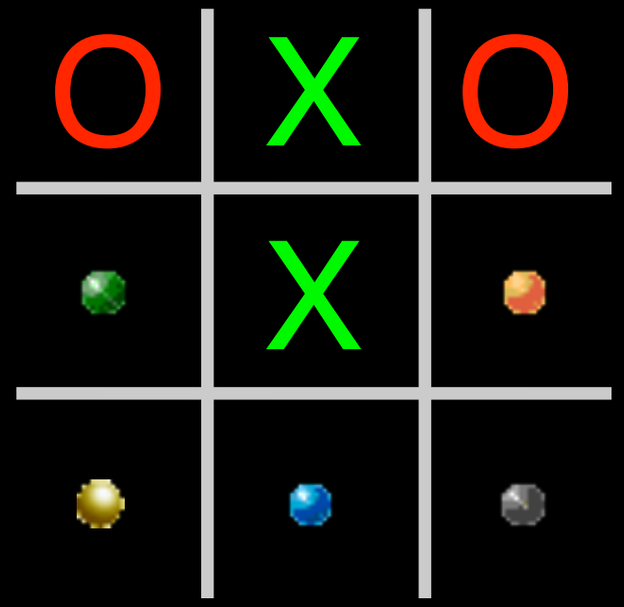


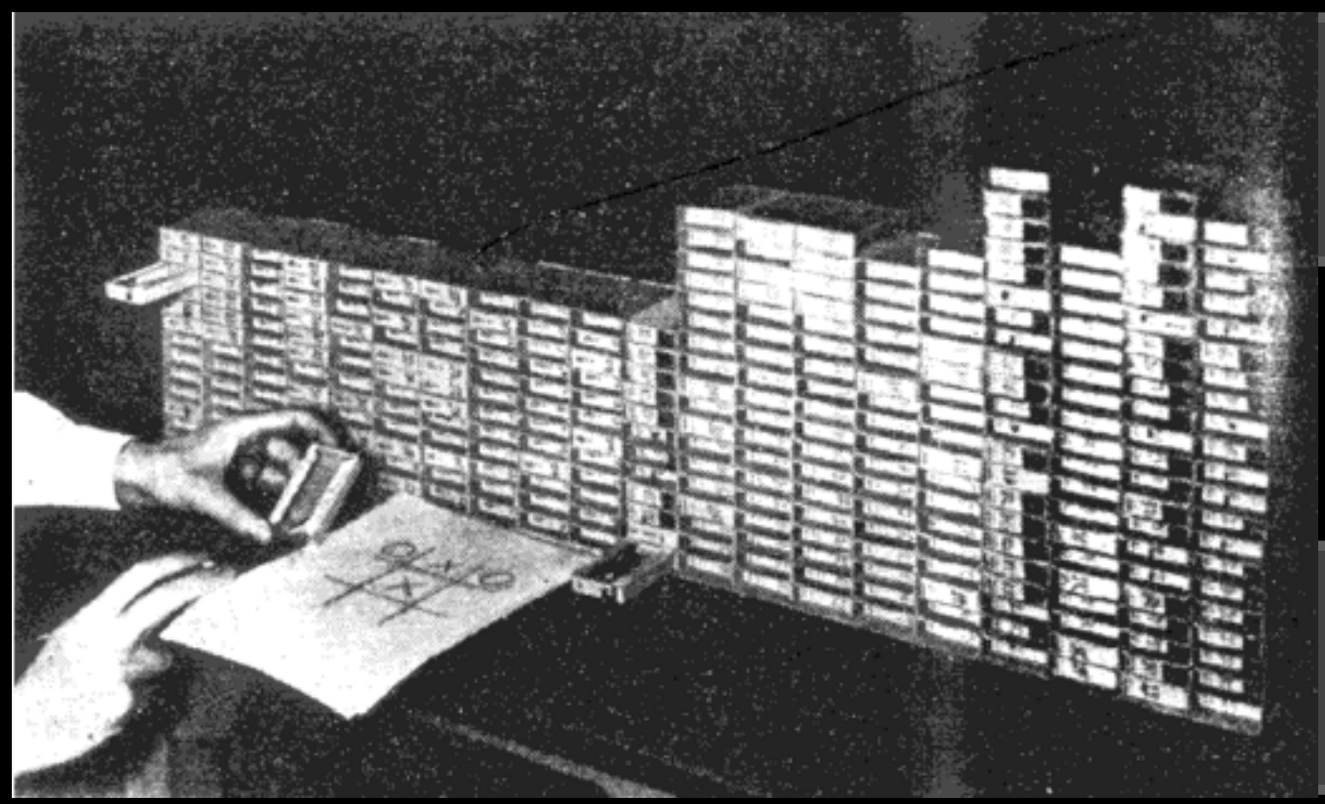
X's move

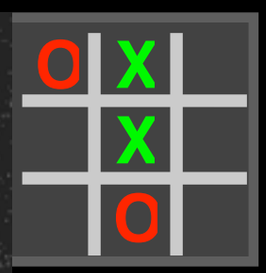


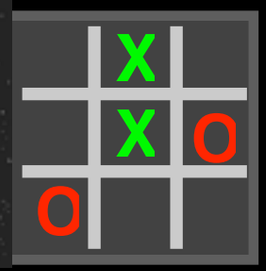
Choose box on the basis of current position

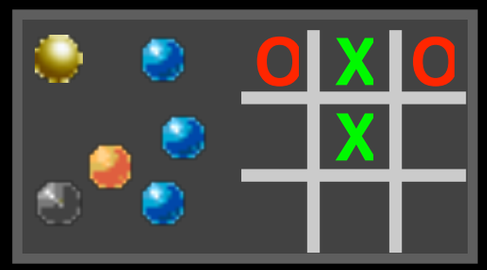
Execute move



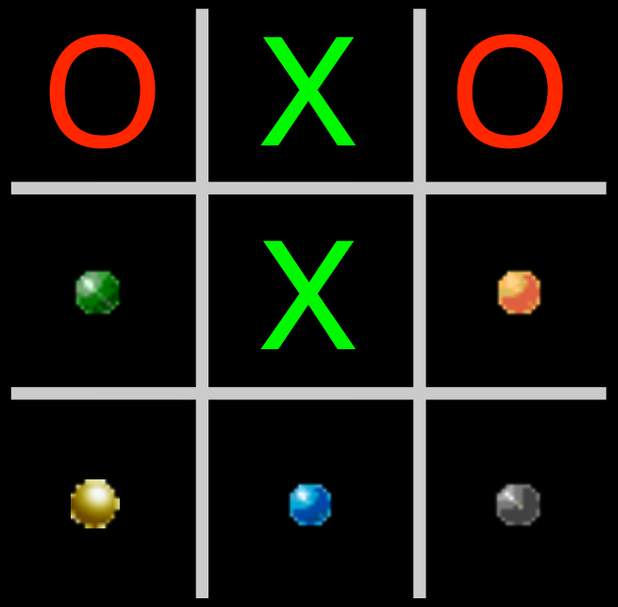






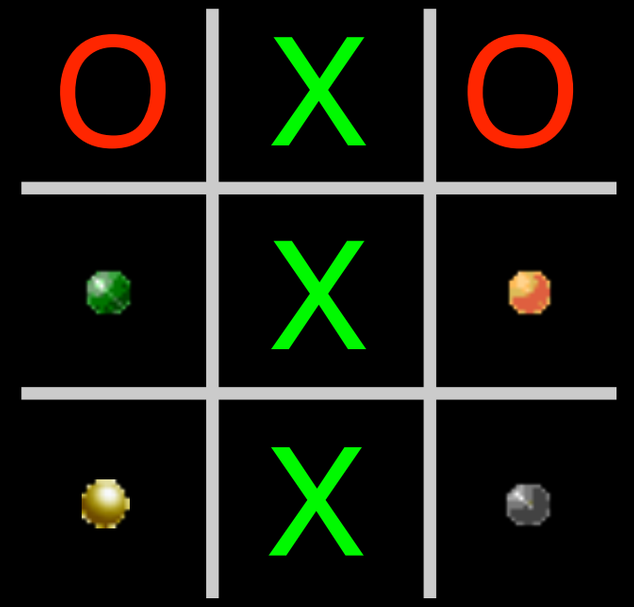


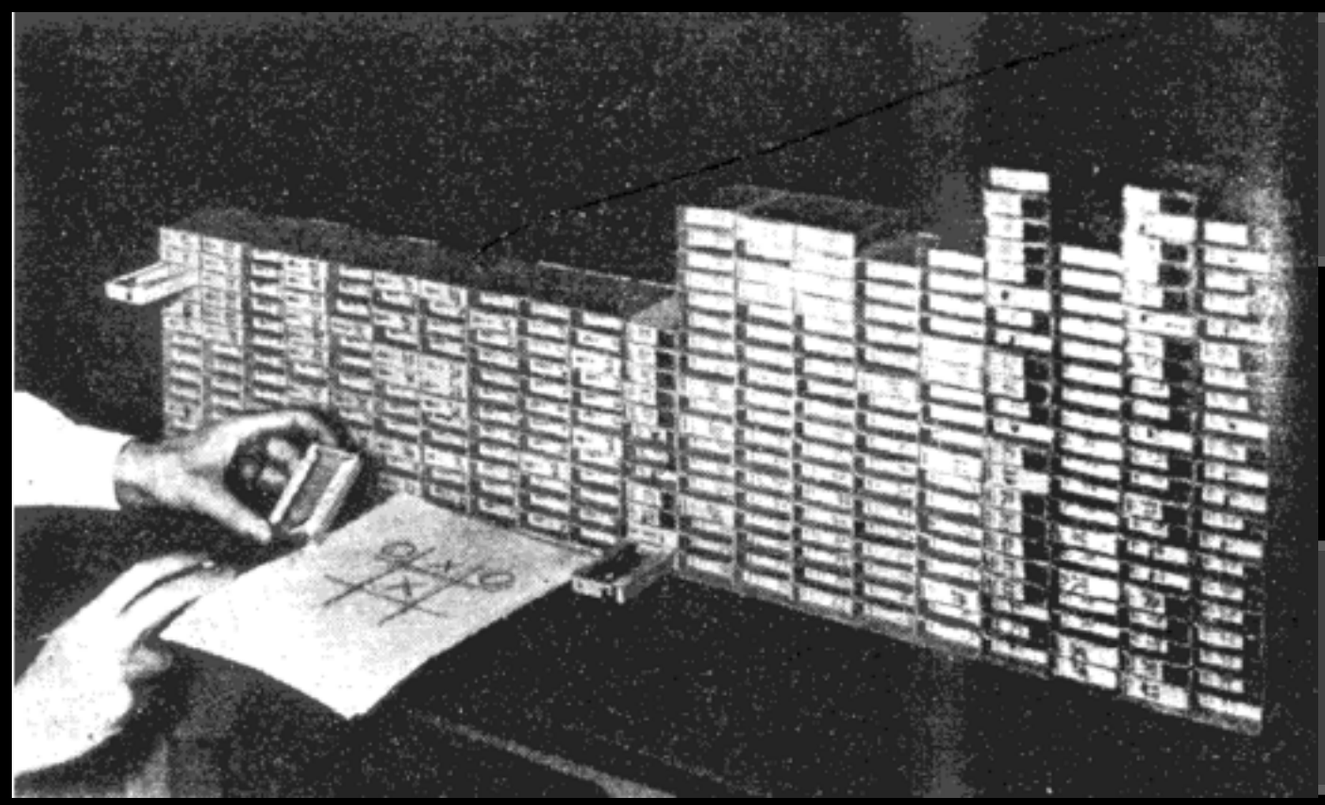
X's move

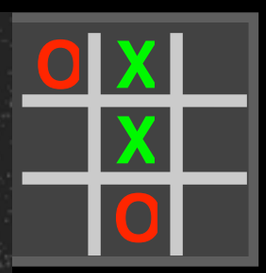


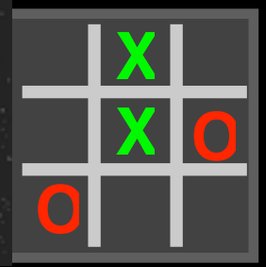
Choose box on the basis of current position

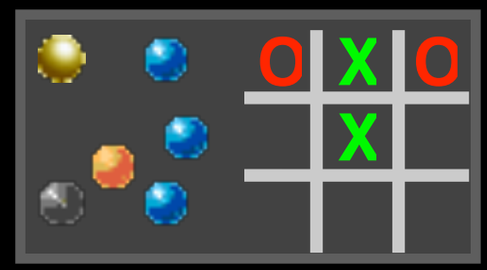
Execute move











Menace

Machine = 287 “boxes” + pearls

Encodes probabilistic function

- P(box, color) = probability of move

Learning a function

- upon *loss*: retain all used pearls
- upon *winning*: put used pearls back and an extra one of the same color

Richard Belmann $Q^*(s,a) = R(s,a) + \gamma \sum_{s'} P(s'|s,a) \max_{a'} Q^*(s',a')$

Menace

Machine = 287 “boxes” + pearls

Encodes probabilistic function

- P(box, color) = probability of move

Learning a function

- upon *loss*: retain all used pearls
- upon *winning*: put used pearls back and an extra one of the same color

Richard Belmann $Q^*(s,a) = R(s,a) + \gamma \sum_{s'} P(s'|s,a) \max_{a'} Q^*(s',a')$

Take-away

- *Machine learning is about learning functions from data*
- *Central to AI and data analysis, and many other disciplines — this is the era of big data*
- *Different schools in machine learning*